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THE CALIFORNIA TUSSOCK-MOTH.

By W. H. VOLCK.

The tussock-moth larva, the so-called horned caterpillar. (Somewhat enlarged.)

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THE CALIFORNIA TUSSOCK-MOTH.

(*Hemerocampa vetusta* Boisd.)

Introductory Note—It has often been remarked that when an insect like the codling-moth produces considerable injury, orchardists are very prone to class all manner of injury to this fruit to this one cause. The injury done to apples and apple trees by the tussock-moth hardly resembles the work of the codling-moth in any particular, still it is very commonly so classed. The present study is the first extended account of the economics of our Western tussock-moth. This insect, which is the only representative of its family in California, differs from other caterpillars, including its nearest Eastern allies, in its remarkable tolerance of arsenical poisons.

C. W. Woodworth.

PRELIMINARY STUDIES.

The tussock-moth caterpillar affecting apple trees in the Pajaro Valley was brought prominently to the attention of the Experiment Station during the first season of the codling-moth investigation in the spring and summer of 1903, and considerable attention was given to it, including certain experiments by Mr. Clarke, who was then in immediate charge of the investigation in this valley.

It was then noted that the paris green spraying, as conducted for the control of the codling-moth, did not destroy these larvæ. Mr. Clarke found that caterpillars of this species inclosed in a cage with thoroughly sprayed leaves were able to develop, going through their normal transformation to full maturity, and finally laying eggs in an apparently normal manner.

In the spring of 1904, Mr. C. H. Rodgers, the Horticultural Commissioner of Santa Cruz County, sprayed trees, using the Kedzie formula as given in Bulletin No. 155 of this Station, as a special experiment to aid us in determining its efficiency as a control for the tussock-moth. The spraying was done in a most thorough manner and frequent observations were made, as in the previous year. Some of the caterpillars were inclosed in a jar and fed on thoroughly sprayed leaves only. Neither the insects on the trees nor those inclosed in the jar seemed to be materially affected by the poison and succeeded in developing into the adult moths.

During that season the insects prospered rather better than usual and it was noted that an unusually large number of egg masses had been deposited on the trees in many of the orchards. Noting this condition and because of the failure of the spraying experiments, Mr. Rodgers

advised the orchardists to rely on the older "hand-picking" method—gathering the egg masses as thoroughly as possible during the winter and destroying them.

Mr. Rodgers and one or two orchardists carried out this program, collecting large quantities of the eggs. As had been anticipated, the tussock-caterpillars became a serious pest in 1905 and wrought thousands of dollars' damages to the apple crop; but where the egg masses had been very carefully picked off the injury was not excessive, although rather too severe to be viewed with equanimity.

The serious injury wrought in orchards where the eggs had not been picked off led many more of the orchardists to apply this method thoroughly during the winter season of 1905 and 1906.

In all there were at least fifty orchardists who went over the trees at least once, and several picked them off two or three times. Others were content to instruct the pruners to remove such of the egg masses as they could discover. In the latter part of May, 1906, we had several hundred apples of the Bellflower and Newtown Pippin varieties picked off indiscriminately in orchards where egg picking had been done thoroughly, and also in unpicked orchards near by for a check. These orchards were of course in the badly infested section, and those selected as check orchards were in each case the one most nearly comparable with the other with which it is contrasted.

It will be seen by referring to the table that the average percentage of injured apples in the egg-picked orchards was 23.5 per cent, as against 65.6 per cent in those unpicked; or a saving, due to picking, of 42 per cent. Where a good crop is obtained, this saving means a considerable profit on the investment required to remove the eggs.

EGG-PICKED.				NOT EGG-PICKED.		
Orchard.	Crop.	No Times Picked.	Per Cent of Injury.	Orchard.	Crop.	Per Cent of Injury.
A. N. Judd	good	3	31	Campbell	light	76
Sanborn	light	2	27	R. W. Eaton*	good	58
C. H. Rodgers	fair	3	16	W. H. Wiley		63
C. H. Rodgers	fair	3	16			
C. G. Redman	fair	2	26			
Average			23.5	Average		65.6
Saving due to picking			42			

*Not picked until too late.

The table also shows that carefully going over the trees two or three times is productive of good results; indeed, it is the last few egg masses that count. The two orchards of C. H. Rodgers were perhaps the most carefully picked of any in the valley, while adjoining orchards not egg picked lost over 50 per cent. These orchards of Mr. Rodgers average 12 per cent better than those where the picking was less thoroughly done.

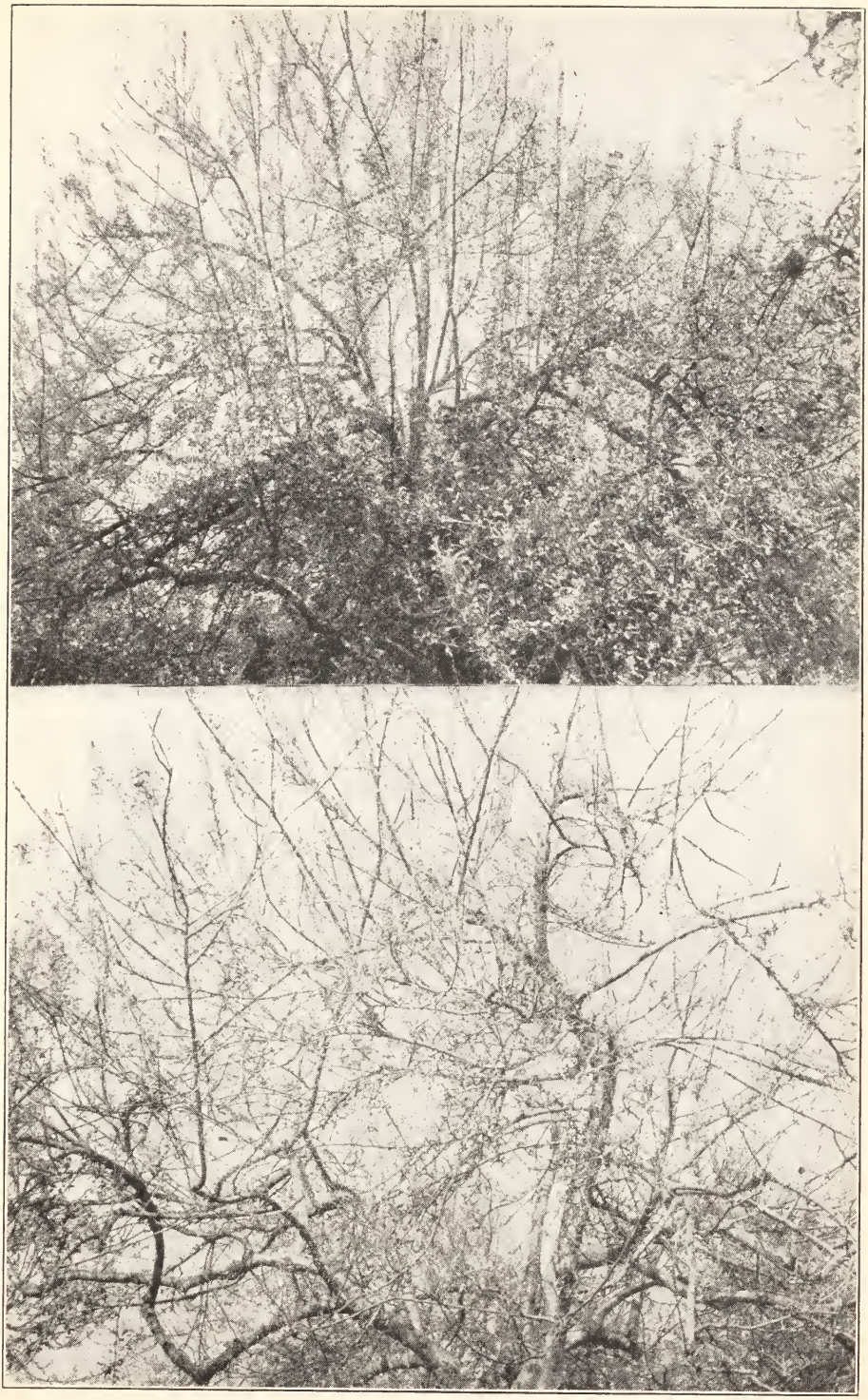

FIG. 1. Defoliation of Bellflower trees by tussock-moth larvæ, first the tops and then the whole tree.

DISTRIBUTION.

The tussock caterpillar is very thoroughly distributed over the Pajaro Valley and the adjoining hill sections. It also occurs over the greater portion of California. In the Pajaro Valley, while it is to be found everywhere, it varies greatly in abundance, and during the last three seasons its worst ravages were confined to certain definite areas. In

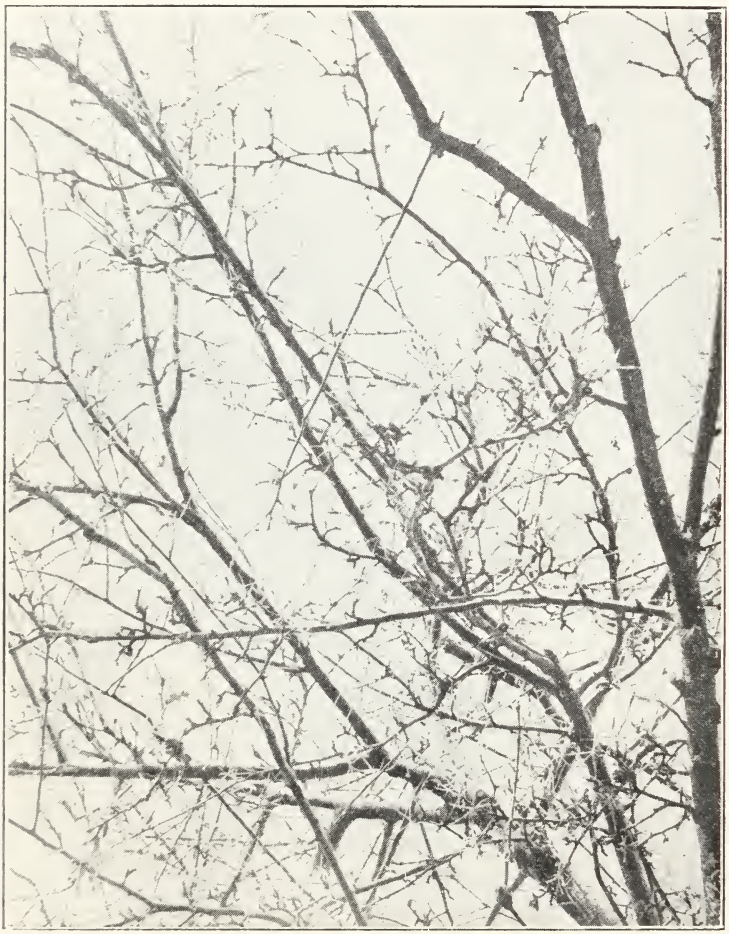

FIG. 2. Complete defoliation by the tussock-moth larvæ.

1891 to 1892, according to Mr. A. N. Judd, in a limited area, known as the Blackburn orchard, the trees were defoliated and surrounding places were also badly infested. Something then greatly reduced the numbers of this insect until it was hardly noticed; but in 1903 they again appeared in destructive numbers in the original locality, as well as in several other areas, mostly in the older orchards, and especially

near town and toward the beach. These areas are surrounded by a widening circle of less serious infestation. If the increase continues most of the lightly infested areas will be in very bad condition next season, and the general infestation much more evident.

FOOD PLANTS.

This caterpillar is commonly found on the live oak and the yellow perennial lupin (*Lupinus arboreus*) that grows along the beach. In the orchard it feeds on apple and cherry trees, and when very abundant is found feeding on walnut and numerous other plants; but apparently, in such cases, these insects have wandered from their original food plant.

On the lupins at the beach the egg masses do not hatch as early as in the orchards; in fact, the larvæ are often abundant in this locality in August and September, which would bring some of the hatchings as late as June.

LIFE HISTORY AND HABITS.

There is one generation of the tussock-moth caterpillar a year. The moths which emerge in May, June, and July deposit eggs that do not hatch until the following spring. The caterpillar requires from forty-five to sixty days for its development, varying according to the

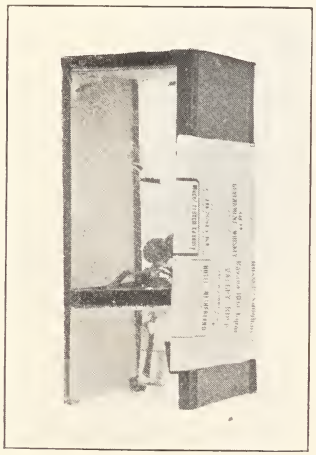

FIG. 3. Form of breeding cage found preferable for rearing tussock-moth larvæ.

FIG. 4. Another form of breeding cage used in these experiments.

temperature and sex. The females require a longer time to reach the spinning-up stage than the males, and are also much larger. The tussock-moth larva molts or changes its skin four times in the course of its development. This makes five larval stages, and at the end of the fifth stage the adult larva spins a cocoon, composed of silk and the hairs which cover the body. These cocoons are not very strong, but

entirely surround the larva and afford a good degree of protection to the insect during the pupa stage. Shortly after spinning the cocoon the last larval skin is shed and the pupa stage begins. In from sixteen to twenty-seven days from this molt the adult moth emerges. Fertilization ordinarily takes place at once, and within three or four days the female deposits its eggs.

In order to carefully follow this development and determine accurately the time required for the various stages, a number of newly hatched larvæ were placed in breeding cages in the laboratory and also in muslin-bag cages which were tied over small branches in the orchards.

The cages found most satisfactory for use in the laboratory were constructed of glass and cardboard, in such a way that the water given off

FIG 5. Cloth bags used as breeding cages in the orchards in the study of the tussock-moth larvæ.

by the living twig placed within it, could readily escape, thus maintaining a fairly normal atmosphere. The twig was kept fresh by a small bottle of water fixed beneath the floor of the cage, in which the cut end was placed. By renewing the twig with sufficient frequency the natural feeding conditions of the insect could be closely followed.

Fig. 3 shows one of these normal atmosphere cages in operation. In the muslin-bag cages which were tied over branches in the orchards, outdoor conditions were perhaps somewhat more nearly attained. The results obtained in these two kinds of cages closely approximated each other, so it is fair to conclude that the normal life history of the insect has been practically determined. Fig. 5 gives a very fair idea of the appearance of the muslin-bag cage.

A series of breeding cages, started March 17 with newly hatched larvæ, will illustrate the results obtained by laboratory methods. The notes show the following data:

Mar. 17—Eggs hatched.
27—One entering somnus.
29—One molting.
Apr. 2—The last one entering somnus.
5—One entering second somnus.
6—The last one molting.
7—One passing second molt.
13—The last one entering second molt.
15—One entering third somnus.
17—The last one passing second molt.
20—One passing third molt.
22—The last one entering third somnus.
26—The last one passing third molt.
28—One entering fourth somnus.
May 1—One passing fourth molt.
3—The last one is in fourth somnus.
6—One spinning up.
7—Last one passing the fourth molt.
21—First male has emerged.
23—The last one spinning up.
June 4—First female has emerged.
7—Last female has emerged.
12—Last male has emerged.

In explanation of the above it should be said that the somnus is the resting condition entered into preceding each change of skin; the molt the close of the somnus, and the insect soon thereafter begins to feed; spinning up is the formation of a cocoon. After cocoon is made there is a somnus of about two days, and then the insect becomes a pupa and finally the adult insect emerges.

Putting the data above in another form, the length of time occupied in passing each feeding stage and somnus for the slowest and the most precocious is as follows:

	First Insect.	Last Insect.
First stage	8 days	15 days
somnus	2 days	4 days
Second stage	7 days	7 days
somnus	2 days	4 days
Third stage	8 days	5 days
somnus	5 days	4 days
Fourth stage	8 days	7 days
somnus	3 days	3 days
Fifth stage	5 days	16 days
In cocoon	15 days	20 days

The first cocoon was produced in forty-eight days, the last in sixty-five; the first male moth in sixty-two days, the last in eighty-five. The average of the males was about seventy-five days from the hatching of the egg; the average for the females was about seventy-eight days.

The orchard experiments may be represented by the cage bearing our laboratory number 13, an account of which is as follows: A large number of tussock-moth larvæ just hatched were placed on a Newtown Pippin branch inclosed in a muslin bag. A considerable variability was noted in this experiment. All the larvæ were hatched at about the same time (March 29); by April 6 a great difference in size was noted: by April 10 some had emerged from the first molt, but the majority had not emerged until April 12. On April 21 practically all had emerged from the second molt, and some were entering the third, but a few were still in the third molt May 5. On May 7 some had entered the fourth molt, and on May 11 some had emerged from the fourth molt, and one male was spinning up. A few were still in the fifth larval stage June 2. So, while the average length of larval life history was fifty-five days, some have required more than sixty-seven days to reach the pupa stage.

The average period occupied by these insects noted during the course of the experiments is as follows:

First stage	11 days
somnus	2 days
Second stage	6 days
somnus	3 days
Third stage	6 days
somnus	2 days
Fourth stage	9 days
somnus	3 days
Fifth stage	12 days
In cocoon	24 days

It will be seen on comparing the above with the corresponding table that the results obtained in the laboratory breeding cages are quite closely alike. It was also brought out by these experiments that the length of the larval life differed with the sex, being about 55 to 65 days for females, while the males require only 50 to 55 days to reach the spinning-up stage.

HABITS.

On hatching, the young larvæ remain clustered over the egg mass until they have gained their normal nearly black color, which may require two or three days. In the meantime, they appear to be feeding on the material which holds the eggs together. Those larvæ which hatch in the interior of the egg mass necessarily have to burrow their way out through this tough binding substance, and the mass eventually appears riddled with these punctures.

This hatching occurs in the orchards about the time the new leaves are expanding; but there is a great variability in the time of hatching, some emerging early in February, while others are still hatching as late as April or even May.

After the larvæ leave the egg mass they wander to the near-by buds and commence feeding. This early feeding is in the form of minute punctures in the youngest leaves and blossoms, and the young leaf stems are also attacked. As the larvæ grow older they still retain their

FIG. 6. Tussock-moth larva. About one-half larger than natural size.

habit of burrowing into the fleshy tissue, and so do much damage to the young fruit. They become, however, more and more leaf feeders as time advances, and the older insects do little damage to the fruit.

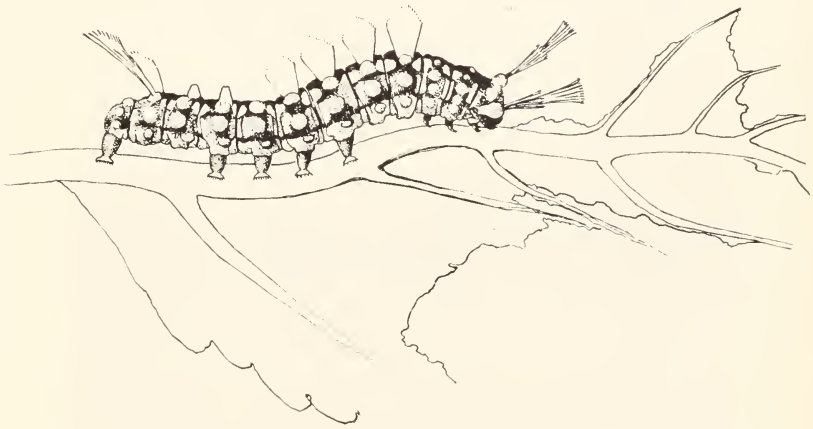

FIG. 7. The same larva as in Fig. 6, with hairs removed to show color and structure of the body.

The larvæ feed at all times of the day and are not gregarious in habits; those from one nest will become very generally distributed over the tree before the larval life is complete.

The molts are passed in more or less protected places, often on the under side of the leaves. Before molting, the larvæ spin a thin carpet of silk on the surface where they expect to remain during the molt. The molt is accomplished by a circular break near the head; the larvæ

FIG. 8. Tussock-moth cocoon masses on the trunks and limbs.

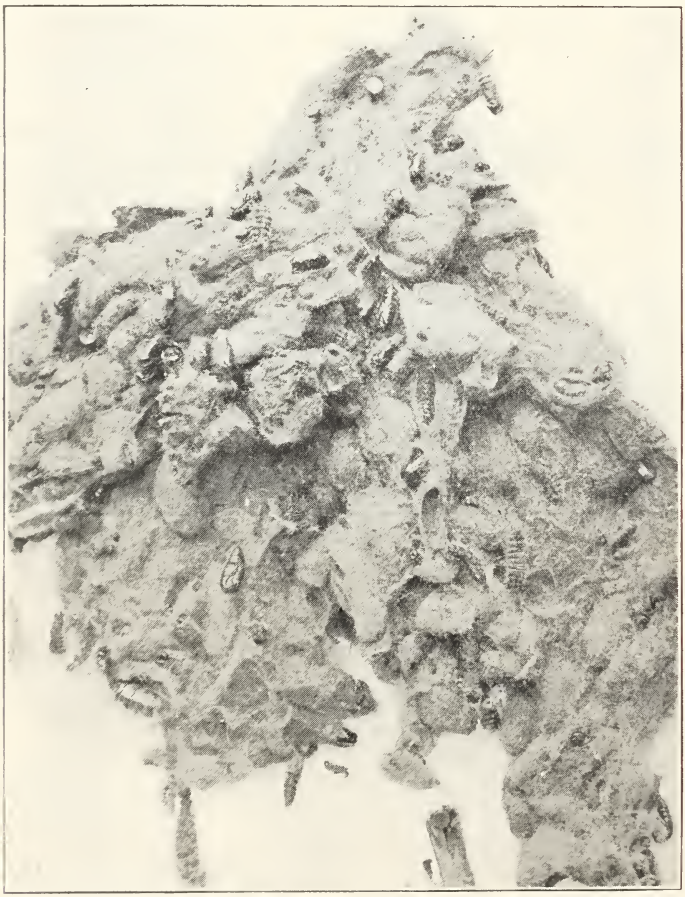

FIG. 9. Mass of cocoons of the tussock-moth. Some of the cocoons have been torn open, revealing pupæ of both sexes. (About two-thirds natural size.)

crawl out of the old skins and remove the head shell later. While the larvæ are normally quiescent for some time preceding the molts, they are, however, able to walk if disturbed, and may change their position before emerging.

The larger larvæ often assume a wandering habit, which causes them to leave the original food plant and seek others, sometimes at a considerable distance away. Isolated larvæ are often found on young trees

FIG. 10. Tussock-moth cocoons on smaller twigs.

several hundred feet from a nest. It is possible, also, that the very young insects may have been carried by the wind and birds and so aid in the general distribution. As the female moth is wingless, the distribution of the species must take place exclusively in the earlier stages.

When the larvæ are fully developed they select somewhat protected places on the trunks of trees and the under side of branches, where they spin up sometimes in masses of cocoons; when the caterpillars are very numerous, these masses may be plastered over the trunk in the form of a blanket several inches wide. Fig. 8 shows several of

these blankets on the trunk and large limbs of an apple tree. Fig. 9 is a view of one of these masses taken against a white cloth. A close inspection of this illustration will show the pupæ of male and female tussock-moths protruding from the cocoons, which have been torn open in removing them from the tree trunk. As the males spin up first they often form masses by themselves, the females spinning their cocoons elsewhere.

The caterpillars sometimes also spin up on the under side of bunches of leaves at the end of small twigs. The leaves are then securely webbed to the twig by the caterpillars before the cocoons are spun. Some of these cocoons are shown in Fig. 10. The spinning-up habits of the caterpillar then result in a general distribution of the cocoons over the surface of the tree, as well as large masses on the trunks, and also on fences and other suitable objects in the vicinity.

FIG. 11. Female moths just emerged and resting on cocoons.

When the moths emerge the males fly about in search of receptive females. The females have a greatly developed abdomen filled with eggs. The legs are fairly well developed, but the wings are rudimentary and unadapted for flight. The female is so heavy that it makes little effort to crawl about, but usually remains clinging to the mass of cocoons from which it has emerged. Here it also deposits the egg mass, usually attached to the cocoons, but sometimes is directly cemented down to the twig. The laying of the eggs takes place in a very few days after emergence.

The males are supposed to be attracted by the odor of the females, and will go considerable distances to find isolated insects. They have often been noted attempting to gain entrance to the muslin-bag cages where the females had emerged.

Mating may take place at once after the female has emerged, or a considerable time may elapse. The eggs are often laid within an hour or two thereafter. While laying eggs the female remains stationary, building up the mass by moving the tip of the abdomen to and fro. The eggs are deposited in a fibrous cementing material, which completely covers them and holds the mass together very firmly, and also makes a strong attachment to the body against which the mass is deposited. As the eggs are ejected the abdomen of the moth slowly contracts, making the insect very much smaller than it was before the egg-laying commenced.

The males fly during the day and also in the evening, or possibly all night when the weather conditions are favorable.

The larvæ and female adults are remarkably hardy. The caterpillars can withstand long periods of starvation and will develop in confinement under conditions which would kill many other insects. Some larvæ developed from eggs in a Mason jar with the lid closed down, their food for the most part being a rotten apple; but this diet was varied at times with some apple leaves sprayed with arsenate of lead.

Another interesting fact about the larvæ is their apparent sense of direction, for when beaten from the trees they lose very little time in finding their way back to the trunk. This ability to find the trunk of the tree seems to be due probably to vision, as any object such as a post standing erect will attract them. That the finding of the tree trunks is not due to accident can be readily seen, for when the caterpillars are shaken from the trees they soon form into lines which converge at the trunk, and only a few can be found aimlessly wandering about.

NATURAL ENEMIES.

As this caterpillar is a native of California, we might expect it to have parasitic and predaceous insect enemies, as well as diseases.

Some experiments were undertaken with the idea of determining these as far as possible. The method of procedure was to collect specimens in the field at various dates and stages of development and keep them for the remainder of their period of development in muslin-bag cages tied over apple branches. It was thought that this would prevent any infestation by parasites after the date of collection.

There were in all fifteen of these experiments, the dates of collection ranging from March 24 to April 26. The data obtained are embodied in the table below, from which it will be seen that no parasitization occurred until April 11. All the collections made after that date contained parasitized larvæ.

The only parasites obtained in these experiments were Tachina flies. These parasitic flies resemble in general appearance the house fly, but most of them are larger.

In addition to the collections of larvæ, a number of collections were made after spinning-up had occurred. These were kept in paper bags in the laboratory. All the pupa collections showed a liberal percentage of parasitization, in some cases as high as fifty per cent. The majority of the parasites taken were the same kind of Tachina flies obtained from larvæ, but the pupa collections also showed several species of Ichneumon flies and other parasitic wasps. There is also a Chalcid parasite which develops in the larvæ and kills them before they reach the spinning-up stage. In this case the parasitized caterpillar remains fastened to the leaf or twig on which it dies and the adult larvæ of the parasite emerge from the caterpillar and pupate in a row on

each side of the parasitized insect. Twenty to thirty parasites develop from a single larva.

There is but little evidence of predaceous insect attack on this caterpillar or of it serving to any extent as food for birds.

The eggs are attacked by a minute hymenopterous parasite (*Telenomus orgyiæ* Ash). This looks like a very small gnat, and is found crawling over the egg masses. The larvæ of this parasite develop within the eggs of the tussock-moth and begin to emerge early in the spring. The emergence of the parasite continues, however, until after new egg masses have been deposited.

The egg masses are also attacked by the larvæ of a Dermestid beetle. This larva is brownish colored and covered with long hairs; it is able to crawl rather rapidly, but may remain still if disturbed.

The egg parasite and the Dermestid beetle are the most useful parasites of the tussock-moth, as, by attacking the eggs, they prevent the caterpillars from hatching, the efficiency depending on the abundance of the parasitization. The other parasites attack the larvæ only after they have developed and completed their injurious attacks on the fruit and leaves.

While parasites have been very abundant they have not destroyed more than fifty per cent of the caterpillars, many moths having emerged and deposited their egg masses. So, if the egg parasite and Dermestid beetle do not become much more abundant, or some other cause of death intervene, there will be a liberal infestation of the orchards again next season.

Diseases were scarcely at all in evidence among the larvæ. A few larvæ died early in April, apparently from a bacterial disease, but caterpillars forced to feed on leaves wet with water containing an infusion of the dead bodies did not result in infection. Three of these experiments were tried.

The following table gives the breeding-cage records of parasitization:

Date.	Orchard.	Egg Masses Obtained.	Death Without Reproduction. Not Parasitized.		Parasitized.
			Male	Female.	
March 24	Eaton	4		4	0
March 24	Eaton	14		5	0
March 25	Eaton				0
March 25	Eaton	2	2	6	0
March 31	Eaton	4		9	0
April 2	Eaton	7		4	0
March 30	Eaton	11		13	0
April 2	Tuttle	9		7	0
April 6	Tuttle	4	1	4	0
April 11	Eaton	2			2
April 12	Eaton	27		7	5
April 22	Eaton	15		4	5
April 26	Judd	10		8	9
April 28	Campbell				9
April 14	Eaton	5			3
April 14	Eaton	6			1

It will be seen by referring to the above table that a number of females failed to reproduce; that is, they died either in the pupa case or shortly after emergence without laying eggs. In all of these cases the cuticle of the abdomen was partly rotted away, exposing the eggs. This disease in some cases killed over fifty per cent of the females, while the males almost invariably emerged.

While the natural enemies of the tussock-moth caterpillar are not to be depended upon to control the insect year after year, yet it is evident that, due to their irregular action or to some other cause equally uncertain in its action, a great variability in abundance is brought about. An instance of sporadic increase came under our notice in the fall of 1903, when the lupins along the beach of Monterey Bay in the vicinity of Port Rogers were very badly infested, but the insect has not been abundant there since. Examinations in that region during the past two seasons have shown that the egg masses were very largely destroyed by the Dermestid beetle, before referred to, and that the egg parasite is also abundant. Other parasites are also in evidence, and this parasitization may account for the greatly decreased numbers of the caterpillars along the beach.

This insect has also experienced a similar rise and fall in abundance in the apple orchard, having almost disappeared during a long period of years preceding 1903. Whether or not the tussock caterpillar will be a serious pest in 1907 can only be a matter of conjecture, for, as has already been stated, the eggs have been laid and only their destruction by natural or artificial means can prevent an abundant hatching of young caterpillars in the spring.

POISONING EXPERIMENTS.

The fact that the tussock caterpillar is not readily poisoned by arsenicals has been alluded to in the opening paragraphs of this bulletin. It was hoped, however, that some method of application might be discovered which would prove successful as a means of control.

Some laboratory experiments were conducted in 1905 with this end in view, and it was found that the newly hatched larvæ were more readily poisoned than the more mature insects.

Arsenate of lead was the material experimented with. When the foliage was thoroughly covered with this insecticide applied at a dilution of 3 to 6 pounds to 50 gallons of water (the wet weight of the material as taken from the keg), and newly hatched larvæ were placed upon it, the majority of them died from arsenical poisoning; but even then some survived and only succumbed after prolonged exposure to thoroughly poisoned leaves. Slightly older insects were found to be extremely resistant; some survived four weeks, when their only food was leaves literally whitewashed with arsenate of lead. These larvæ

ate but little, and doubtless died from the combined effects of starvation and arsenical poisoning. It was then evident that even early spraying with heavy doses of arsenate of lead might not prove successful, for, added to the resistance of the insects would be the difficulty of keeping the rapidly expanding foliage covered with poison. The feeding habits of the young caterpillar were also against success, as they worked largely on the buds and blossom clusters, which were very difficult to cover with spray. Also, the frequent rains that occur in the early spring tend to render spraying ineffective; and last, but not the

FIG. 12. Foliage sprayed with arsenate of lead for very young larvæ of the tussock-moths.

least important, the prolonged period of hatching, which covers nearly four months, is against the success of such a spraying campaign.

Notwithstanding all the apparent difficulties, some early spraying experiments were undertaken this spring, notably in orchards of Messrs. M. B. Tuttle and R. W. Eaton. Spraying began in the Tuttle orchard on March 8, and continued, owing to delays caused by the rain, for about three weeks. Arsenate of lead was used at the rate of 3 pounds to 50 gallons of water, and the trees were thoroughly sprayed. The caterpillars were hatching abundantly at this time, and there were also a great number of larvæ which had passed the first and even the second molt. Spraying in the Eaton orchard was not commenced until

March 29. Here 5–5–50 Bordeaux was used, with 3 pounds of Swift's arsenate of lead to 50 gallons of the mixture. The trees were still in blossom at this date and the tussock-moth larvæ were yet hatching abundantly, but many of them were in more advanced stages than when spraying was commenced in the Tuttle orchard. The spray was thoroughly applied in each case and many young larvæ were killed, but the treatment did not obviate the necessity of beating the trees several times later, in order to prevent their defoliation, and, in spite of all efforts, the fruit was badly damaged.

PARIS GREEN DUSTING EXPERIMENTS.

Mr. A. N. Judd had been experimenting with a mixture of sulfur, paris green, hydrated lime, and powdered bluestone, applied with a dust blower. The results led him to believe that his mixture was of special value as a remedy for the tussock caterpillar. Paris green was probably the most effective ingredient, but in order to determine this the experiments recorded below were tried.

EXPERIMENT 1.	Paris green	1 part
	Hydrated lime	20 parts
	Bluestone	4 "
	Total	25 "

After one week several worms were found dead; many others much shrunken. Examined again in June, one male had emerged and one pupated; others had died in larval stage.

EXPERIMENT 2.	Paris green	1 part
	Sulfur	4 parts
	Hydrated lime	20 "
	Total	25 "

After one week several worms were found dead; many had eaten but little. Examined again in June, all were found dead in the larval stage.

EXPERIMENT 3.	Paris green	1 part
	Hydrated lime	24 parts
	Total	25 "

After one week several worms were found dead. Examined again in June, one male had reached pupa stage, but was very small, and all the others died in the larval stage.

EXPERIMENT 4.	Paris green	1 part
	Hydrated lime	16 parts
	Sulfur	4 "
	Bluestone	4 "
	Total	25 "

After one week several were found dead, others had eaten little. Examined again in June, all were found dead in the larval stage.

The applications were made to small branches with an insect powder gun and the leaves were very thoroughly covered. These branches were then inclosed in muslin bags, along with a number of large-sized tussock-moth larvæ. On referring to the table, it will be seen that the results were practically the same in all the experiments, showing that paris green is the effective portion of the mixtures. An experiment was also tried with a mixture of sulfur, hydrated lime, and bluestone; but in this case the larvæ all survived and were apparently as healthy as if feeding on untreated foliage.

Under the protection of the bags the dust mixtures remained on the foliage for a long time, but some applied at the same time to unprotected branches was soon removed by the action of the wind. The foliage in the bags was also somewhat injured.

It is apparent, then, that while this concentration of paris green, thoroughly applied, is capable of killing even large-sized tussock-moth larvæ when the foliage is kept covered, the practical difficulties in the way of its use are numerous. The loss of the dust through the motion of the leaves in the wind is probably the worst difficulty, also the newly expanding foliage would have to be kept covered. With a dust blower, however, it is possible to go over an orchard rapidly, and the applications might be repeated every three or four days from the first of March to the middle of April. It would be dangerous to continue the treatment later than April 15, on account of the foliage injury. If such a program were carried out it would doubtless result in the killing of a large number of tussock-moth larvæ.

The dust mixtures used by Mr. Judd contained 3 pounds of paris green to 50 pounds of hydrated lime, or 1 pound of paris green to 16.6 pounds of lime. The mixture used in our experiments consisted of one part of paris green to 12 parts of the dilutent.

OTHER EXPERIMENTS WITH STOMACH POISONS.

While the arsenicals are the only substances with which there is a reasonable hope of success, yet some experiments were tried with other poisons, such as phosphorus and cyanides. These experiments gave only negative results, the failure being in a large measure due to the difficulty of retaining these poisons in an active form when spread over apple foliage in a finely divided condition.

CONTACT INSECTICIDES.

The tussock caterpillar, owing to its protection of hairs, is very difficult to wet with a spray, and so the use of the contact insecticide offers little hope for success. It was, however, advisable to try such sprays. Two contact spray experiments were tried in the Eaton orchard March

27, 1906. These consisted of a five per cent mechanical mixture of kerosene oil, and whale-oil soap. The whale-oil soap mixture consisted of 1 pound to 7 gallons of water, with the extract from 1 pound of quassia chips added. Fifty gallons of each spray were applied. A power outfit with a rapid agitator was used, and the spraying was done with fair thoroughness, although the men handling the nozzle were new at the work.

As a result a few specimens were found to be killed with the whale-oil soap, but the kerosene was apparently harmless, and in neither case was a practical efficiency obtained. Later some experiments were tried with pyrethrum applied as a spray and a strong soap solution (common laundry soap). The pyrethrum was ineffective. The soap solution killed about fifty per cent of the larvæ, but it later caused most of the foliage to fall.

These experiments are sufficient to illustrate the futility of the use of such contact insecticides as are now known.

DAMAGE DUE TO THE TUSSOCK-MOTH CATERPILLAR.

While this insect may become so abundant as to defoliate the trees and so destroy the crops for one season and partly for the next also, yet these severe attacks are rather rare. The great general injury due to this insect is sustained by the fruit.

Almost from the first the young caterpillars show a decided tendency to eat into the newly formed fruit. They often begin before the blossoms have opened and continue until the larvæ are half grown. The mature larvæ are more strictly leaf-feeders.

Some varieties of apples are much more severely attacked than others, notably Newtown Pippins and Bellflowers. The injury sustained by the fruit varies from a shallow surface abrasion to a deep excavation, sometimes extending to the core. This injured fruit generally remains on the tree and the wound heals over, becoming covered with scar-like tissue. When severely bitten the apples are much distorted and have to be culled out, thus often resulting in a considerable loss to the producer.

Reference to table on page 192 will show that the total injured fruit may run as high as seventy per cent. It is not all necessarily a total loss, as some may be sold as seconds.

SUGGESTIONS FOR CONTROL MEASURES.

Spraying.—Spraying with arsenicals has so far proved unsatisfactory, and therefore should not be depended upon. Contact sprays are likewise ineffective, and none of the winter washes can be of any material value, as the eggs are almost impregnable to such treatment.

Picking the Egg Masses.—The egg masses are nearly spherical bodies, grayish brown in color, and average somewhat over a fourth of an inch in diameter. They are therefore very readily seen. The search for eggs is facilitated by the fact that they are usually laid on the cocoons, and when these are on the small branches and twigs the dead leaves secured to the twig by the web spun by the caterpillar also help to locate the eggs.

Egg picking should commence as soon as the leaves fall in the autumn, as the eggs are easier seen at that time than after they have become brown by weathering over winter. It often happens, also, that the thorough cleaning of an orchard requires a considerable time, and it is important to finish before the caterpillars begin hatching.

FIG. 13. Larvæ of tussock-moth feeding on apple foliage and fruit.

To be successful the egg-picking operation must be performed with great thoroughness. It is necessary to remove not only the egg masses deposited on the larger limbs, but those scattered over the small branches and twigs as well. In performing this work the men should use ladders of sufficient height to enable them to reach the tops of the trees. The thorough removal of the egg masses is trying work and the men employed are likely to grow indifferent to the task, unless they are thoroughly impressed with the necessity of finding the very last one on the tree. Even with the most conscientious work, some eggs will be left, especially on large trees, and it has been found that three pickings will still leave eggs.

As it is the last few egg masses that count, some system which will enable one to remove these, as far as possible, is desirable. It is suggested that the men carry a small can of whiting and a paint brush with them, and as the limbs are examined they may be marked. The system to follow would be to mark a principal branch at the base of the tree and then, proceeding upward, mark the laterals as fast as they

are examined. The marking program should be followed out to the small branches which give rise to the fruit-bearing spurs. The mark had best be a ring painted completely around the branch, so that it may be seen from all points of observation. Of course the branches should be observed from all sides, as the eggs are likely to be concealed anywhere. Further precaution should be taken in insisting that the egg masses be completely removed, since a few eggs are liable to be left attached to the stems if this part of the work is not thoroughly done.

Such a system should obviate the bewildering effect of the tree when viewed as a whole, and at the same time enable a man to go over it all without missing any part; and further, this system should enable the men to do the work thoroughly in one operation. The cost of such an operation should not be greatly more than that of less thorough methods, and when considered in the light of results the increased returns in the way of uninjured fruit would make it less expensive. That thorough work pays will be seen by referring to table on page 192. It will be seen that the injured fruit in the Rodgers orchard averaged 12 per cent less than where the work was less thoroughly done. The original infestation in the Rodgers orchard was quite as great as that of his neighbors, and if he had not followed carefully the egg picking for two seasons, his losses would have been quite as large.

FIG. 14. Larva below tar rope band.(Cloth strip was placed on tree for photographing.)

The Disposal of the Eggs.—The egg masses should not be thrown on the ground, for while this method may result in their destruction, it is by no means certain, since it is known that the young larvæ are able to crawl a considerable distance. Thus, if they hatched on the ground in the orchard, some would doubtless find their way to the trees.

The men should carry a pouch swung over the shoulder, in which all the egg masses gathered should be placed. When the eggs have been gathered they may be destroyed by burning. It may, however, prove advisable to foster the egg parasite (*Telenomus orgyiæ*) and the Der-

mestid beetle. In this event the eggs should not be burned, as the parasites are also destroyed by this operation, but they may be left in open boxes distributed through the orchards, in the hope that the emerging parasites will further infest what egg masses still remain on the trees.

The gathered eggs should be removed from the orchard early in February when the caterpillars begin to hatch. If the eggs are then removed to a spot several hundred yards from the nearest orchard, there is little if any danger of the emerging larvæ finding their way back to the trees. In storing the egg masses they should be protected from the weather by a covering of boards and also raised up off the ground.

FIG. 15. The same as Figure 14, but enlarged.

In May the eggs can be returned to the orchard, since the egg parasite is then emerging in force. Some caterpillars may also still be hatching, but observation has shown that the late hatchings do not injure the fruit, and further that they are almost invariably parasitized. The advisability of returning the eggs will be governed by the condition of the orchard. If the egg-picking operation has so completely removed the larvæ that little or no damage results, it may be well to give the collected eggs to some less fortunate neighbors.

Secondary Measures.—After the caterpillars have been allowed to hatch the only treatment which will reduce their numbers is beating the trees. This operation should be commenced early in April, and, like the egg picking, the degree of success will depend on the thorough-

ness with which the work is done. The tree should be vigorously thrashed, and in badly infested orchards three or four beatings will be required to reduce the number of caterpillars below the danger point.

In order to prevent the caterpillars from re-ascending the trees a sticky band must be placed on the trunk. Pine tar, tanglefoot compound, or even crude oil will make such a band. The sticky preparation can be applied directly to the bark, or it may be painted on a paper band which has first been snugly fastened around the trunk. Still another method of application is to saturate a piece of baling rope in the sticky mixture and then tie it around the trunk. Any inequalities which hold the rope away from contact with the bark may be filled with some burlap or cotton waste dipped in the mixture.

FIG. 16. Larvæ below fly-paper band.

The sticky rope band is perhaps the best of all the forms that have been devised, as it is easy of application and does not waste the material as much as some other methods.

The bands are effective as long as they remain sticky, which is generally not more than a week. The length of time that these bands will remain sticky will depend on the weather conditions and the material used. Pine tar, crude oil, and tanglefoot compound have been used extensively here. A tanglefoot mixture can be prepared by melting together, with a gentle heat, 16 pounds of resin and one gallon of castor oil. When the mixture has been prepared it can be thinned to any desired consistency by the use of more castor oil.

A rope band saturated with this mixture, well thinned with castor oil, will remain effective about ten days, which is as long as any of the sticky band materials which have come under our notice will last.

Crude oil of a grade which is very rich in asphaltum also makes a satisfactory band material, but there is some danger in applying this to the trees, as it may at times injure the bark. A pine tar and molasses mixture, using equal parts of tar and heavy molasses, has also given good results.

The use of the band may be advisable, even in an orchard thoroughly egg picked, for if the neighboring orchards are not well attended to there may be a migration of caterpillars into the clean orchard. In

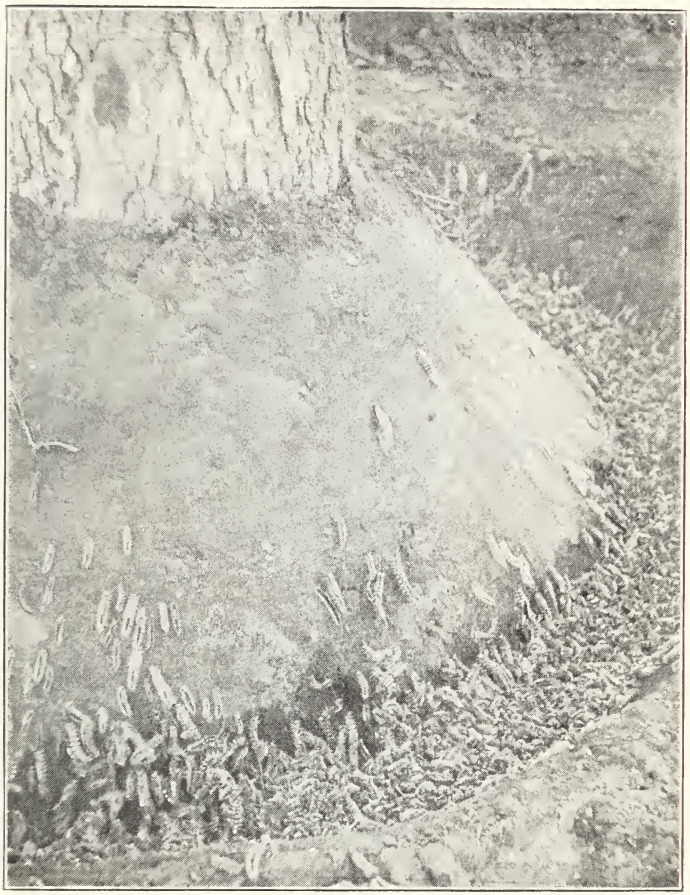

FIG. 17. Earth cone and trench used as a barrier against tussock-moth larvæ.

such a case the bands should be applied early in April, and replenished every ten days until the latter part of May.

SUMMARY OF SUGGESTIONS FOR CONTROL.

Thorough egg-picking should be the main reliance. As secondary measures the use of bands with the beating of the trees, where enough caterpillars escaped the egg-picking work to warrant the expense. Band the tree also when the neighboring orchards are badly infested.

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